2012

Effect of instructional methodologies on student achievement modeling instruction vs. traditional instruction

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EFFECT OF INSTRUCTIONAL METHODOLOGIES ON STUDENT ACHIEVEMENT MODELING INSTRUCTION VS. TRADITIONAL INSTRUCTION

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Natural Sciences

in

The Interdepartmental Program in Natural Sciences

by
Jacqueline Grace Barker
B.A., Louisiana State University, 2007
August 2012

ACKNOWLEDGMENTS

Thank you to Dr. Dana Browne for his time, patience, and motivation to make this project successful. Also, I would like to thank you for being a mentor and a guide not only for this thesis project, but for all other aspects of this program. Thank you to Dr. Cyrill Slezak for all of the advice and information needed to put so many different parts of this project together and especially for inviting Dr. Levi Torrison from ASU to show our cohort the “Modeling” curriculum on which this project is based. Thank you also for serving on my committee as chair and for skillful editing and suggestions. Thank you to Dr. Les Butler for taking the time to serve on my committee and for editing and suggestions.

I would also like to thank the 2010 LaMSTI cohort for the support and advice throughout the entire program. A special thank you to Leslie Blanchard for making sure everything went smoothly and for introducing me to the program. Thank you to Dr. Madden for leading this program and assuming all of the responsibilities that go along with it.

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ABSTRACT

Different teaching styles can impact student learning in many ways. The purpose of this study was to determine the effectiveness of Modeling Instruction on student achievement in a high school Chemistry course. Different tests were used to compare the data at the beginning of a school year and at the end of the school year. The tests used were to determine gains in chemistry content knowledge, abilities to reason scientifically, and attitudes about learning chemistry. The control group was taught by traditional instruction through the use of lecture, note-taking, and textbook guided assignments. The experimental group was taught by the use of the Modeling Curriculum from Arizona State University, which consists of daily group activities, including white-boarding, journal-writing, and self-discovery tactics. As far as concepts in Chemistry were concerned, based on Chemistry Concept Inventory normalized gains, there was a significant gain for the Modeling group independent of students' prior exposure to Physical Science and gender. There was also a positive increase towards favorable attitudes in learning Chemistry for the Modeling sample, based on the Colorado Learning Attitudes about Science-Chemistry. The data in this study shows utilizing Modeling instruction in a high school Chemistry setting is effective for positive gains in content knowledge and attitudes about chemistry.

INTRODUCTION

Teaching is a constantly evolving practice with research and studies eventually being performed to find the best practices. As a teacher, I would be willing to do what is necessary to benefit the education of my students. After four years of teaching, I typically taught my students by lecturing, regular note taking, and by using a textbook. After taking a modeling course myself, I decided to conduct a study on the positive effects of modeling instruction for high school Chemistry students.

In my experience, most teachers use traditional methods of instruction because almost every teacher can give a lecture and use a textbook as a guide to follow. After taking a modeling course myself, I found it very engaging. The use of white boards always kept me busy and I became very curious and eager to want to continue the assigned work to discover the how the outcome would be determined, even though I was already familiar with the material. I became interested in how my own students might be affected by this type of instruction. Most of my students complain about how Chemistry can be so boring so I thought if maybe I changed my method, I could change their minds. This was the origin of this study.

Modeling Instruction was developed at Arizona State University over two decades and its main objective is to develop cognitive skills in students by making models used to understand the physical world. "The modeling view is that students learn best from activities that engage them in actively constructing and using structured representations to make sense of their own experience and communicate it with others" (Hestenes, 1997). The instructional part of modeling is designed to incorporate scientific inquiry by presenting ideas to students and having them investigate together in groups. This format is different from traditional teaching styles because of the teacher guidance during activities and structure. “From the beginning of a lesson, the teacher engages the student in giving an accurate description of the phenomena in question – identifying the relevant systems, components, and variables. Students are guided to an investigation of structure in the phenomena, and, as needed, the teacher introduces appropriate tools for representing that structure” (Hestenes, 1997). As these lessons continue, students begin to understand and memorize the steps for conducting an investigation and gradually begin to work independently of the instructor. A Modeling cycle generally lasts about two weeks and exists in two phases: development and deployment. The development phase is for evaluating a model for a physical system and then constructing a model for that system usually involving the design and completion of an experiment followed by an oral presentation and critique of results. This phase involves applying that model in a variety of new situations to explain, predict, design, or control. The deployment phase also incorporates problem solving followed by class discussion and analysis (Hestenes, 1997). Most of the classroom presentations are done on white boards for each group to present their findings, which often leads to class discussions. Students are also allowed to write in journals to keep a log of their findings in an experiment, discovery, or presentation.

One of the main differences between Modeling instruction and traditional instruction is the way materials and ideas are presented. Generally, in traditional instruction, students learn concepts piece by piece and learn how to put them all together in the end. For example, students learn the different types of reactions and learn how to differentiate between them by performing experiments. A student would have to have a strong knowledge of the different reaction types and how they work to be able to determine what is happening in the experiments. Overall, in a traditional setting, students learn concepts first and then see how they come together in experiments.

Modeling is different in its inherent structure because it introduces a new concept by having students perform the experiment first. A student will not have any background knowledge for the concept when they begin to do the experiment. Beginning with just the experiment means that the students need to work to put the pieces together in order to make sense of it. The students work in groups and brainstorm possible reasons for the phenomena in question before they are given the terms to describe what is happening. A traditional student learns the different types of reactions and determines which it is by experimenting. A modeling student has the facts of the experiment and has to pick it apart and determine what happens, providing reasons for what is occurring.

For example, a single-displacement reaction occurs between silver nitrate and copper. A student that learned traditionally about single displacement reactions can determine that when silver nitrate and copper react, copper nitrate and silver are formed. A modeling student will perform the experiment and know that they started with silver nitrate and copper and ended up with copper nitrate and silver, but they have to determine what happened based only on the materials they started and ended with, having no background in reaction types.

After researching the data on the effects of modeling instruction, a significant gain on content knowledge in college Physics courses was shown (Hestenes, 1997). I would like to know if this same effect on high school students is possible. I am committed to advancing the academic achievements of my students and I consistently adapt my curriculum to ensure their success. If I find out at the end of this study that modeling improved student assessment scores or understanding of chemistry content, I would be eager to change my teaching style. If proven effective, modeling would also be an idea to share with other teachers in my school.

An interesting study compared the results of the Classroom Test on Scientific Reasoning (CTSR) (Perkins et al., 2005) across cultures. This study was to compare the performances between the United States and China of college freshman on physics concepts and scientific reasoning abilities. Test data was collected from three different universities and included over 3000 students between the United States and China, using two tests on content and the Lawson-CTSR. There were statistically different comparisons made between the two groups for the content tests, but not on the scientific reasoning test. This was interesting because it emphasized that training on content knowledge did not have an affect on the development of students' abilities to reason scientifically (Bao, et al). This could also be true for the results of this study.

Chemistry is not a subject most students enjoy because it involves intangible concepts. If students are learning about something they cannot see, often the idea becomes difficult to understand. For example, the very beginning of the modeling curriculum refers to atoms and molecules as particles. This is important because a "particle" is the fundamental single model on which every other idea is based. If the "particle" is understood, it is much easier to build on the chemistry concepts that follow. They continue to be called particles until atoms and molecules are explicitly introduced, which I think make the concept easier to understand. The words "atoms" and "molecules" are Chemistry terms that some students may not have been exposed to prior to a Chemistry class. A particle is an idea to which the student can relate. Atoms and molecules still need to be understood, but discussing them as particles displaying them in diagrams from the very beginning makes a difference in understanding them. During the group aspect of the modeling curriculum, each group is given the same problem to work on. When students are working through these problems, they know their classmates are also solving the same problems in order to reach a conclusion. The idea of presenting to their classmates makes the class structure a little more competitive and motivates students to want to answer correctly. They put forth more effort to answer the questions correctly, so as to get the same answer as their classmates. These techniques engage and motivate the students. Traditional teaching on the other hand, allows students to work on their own or in small groups, so that only one student or one group of students presents their answer to the class. Thus, students are not as motivated when they can rely on someone else to provide the correct answer.

I believe that any student would be more willing to learn and put forth an effort if they are engaged in what is going on in the classroom. Lectures are not the most engaging way to get information across. On the other hand, keeping students active and engaged with hands-on learning tactics would be a good way to keep students interested. I also believe that modeling for students would help to build their confidence when presenting answers to their classmates. Some students never raise their hands to answer questions for fear that they will not have the correct answer; the format of modeling provides ample opportunities for all students to actively participate in their own learning by allowing them to answer questions and give explanations.

LITERATURE REVIEW

In his journal article titled “Modeling Theory for Math and Science Education” (Hestenes, et al. 2010) Hestenes questions the reasons a theoretical physicist should be concerned about an education in mathematics. Throughout his research, he learned of several connections between physics and mathematics. He explains the reasons started with the physics and math separation that happened in the late nineteenth to early twentieth century. It was documented as “the disastrous divorce” when the mathematics profession was separated from physics. It was estimated that by 1980, eighty percent of mathematicians were ignorant of science, and that the majority of those in the discipline thought mathematics to be completely autonomous from science (Hestenes, et al., 2010). This separation also affected the training of math teachers in the elementary and high school curriculum. This dissociation is a fundamental problem in learning and cognition because, as Hestenes claims the “cognitive processes for understanding physics and math are intimately linked and fundamentally the same” (Hestenes et al., 2010). For example, training in math is essential for all physicists, yet math courses have become irrelevant to physics, leading to a current disconnect between the two disciplines. Thus, the current inefficient preparation of K-12 teachers and has become a problem in that it leads to the unpreparedness of students. The origins of Modeling Theory began in the midst of this disconnect to try to close the gap where these two subjects should be treated more intertwined. Math is physics and physics is math; in order to understand one, you need to also understand the other. Physics is the basis of quantitative reasoning in all areas of science. In order to treat the two as one, the idea of the modeling theory was developed.

Hestenes' interest in cognitive science and theoretical physics started when he was trying to improve introductory physics courses. It was during this time that he identified scientific models and modeling as the core of scientific knowledge and practice and tried to incorporate it into his own instruction. He created a research perspective called the Modeling Theory, which continues to evolve to this day. The theory is based on two strands of scientific models and modeling practices that are observable in cognitive science and scientific practice (Hestenes, et al., 2010).

There are three strong reasons for using a model-centered approach for science: theoretical, empirical, and cognitive models. Theoretical models are basic units of structured knowledge where one can make inferences, predictions, and explanations. This analysis cannot be done based on theoretical principles or isolated facts. Empirical models can be directly compared with physical substances and processes. A theoretical hypothesis or general principle cannot be tested without incorporation of a model. Cognitive models are concretely buried in physical intuition and serve as a part of physical understanding (Hestenes, et al., 2010).

Structure is central to the concept of Modeling Theory and therefore defined as a set of relations among the objects in a system. As Hestenes et al. states, "a model is a representation of structure in a given system. A system is a set of related objects, which may be real or imaginary, physical or mental, simple or composite. The structure of a system is a set of relations among its objects. A scientific model is a representation of structure in a physical system or process." Mathematics is the science of structure as defined by optimal precision. Just as science involves using objective models, cognition is about conceptual models, which can be defined as a representation of structure in a mental model." This definition is what enables a "Modeling Theory of scientific knowledge to a Modeling Theory of cognition in science and mathematics" (Hestenes et al., 2010).

Hestenes (2010) proposed the first principle for a modeling theory of cognition, which says that cognition is essentially about making and manipulating mental models. Cognition surrounds a concept with form, symbol, and meaning. The second principle for a modeling theory of cognition says mental models possess five basic types of structure: systemic, geometric, descriptive, interactive, and temporal. This structure surrounds the idea that cognitive research incorporates two general types of category concepts, implicit and explicit. Implicit concepts derive meaning from a web of different associations with at least one mental model. Explicit concepts are stemmed from individual mental images and are defined by public representation. These concepts support the idea that "imagination is the faculty for making and manipulating mental models" (Hestenes et al., 2010). Although human knowledge begins with intuition, that knowledge continues to evolve into concepts and eventually leads to ideas.

This structure begins to connect the science and mathematics models. The physical structure involves real things and events surrounded by physical intuition. The mathematical structure involves symbolic representations surrounded by mathematical intuition. Both structures eventually lead to a mental model.

Knowing how scientific models are constructed and validated leads to an understanding of science. "The great game of science is modeling the real world, and each scientific theory lays down a system of rules for playing the game." To construct valid models of real objects and processes is the object of this game. "The main objective of science instruction should therefore be to teach the modeling game.” This is what was decided should determine curriculum in science. Hestenes said it should be organized around models and not topics because models are the basic units of “coherently structured knowledge.” His implications for instructional design said students should learn a modeling approach to scientific inquiry. This would include proficiency with conceptual modeling tools, qualitative reasoning with model representations, procedure for quantitative measurement, and comparing models to data. “The modeling method of instruction is a student-centered inquiry approach guided by the teacher, as recommended by the National Science Education Standards. The difference is that all stages of inquiry are structured by modeling principles” (Hestenes et al., 2010).

David Hestenes designed, studied, researched, and tested the use of Modeling instruction in Physics courses and laid the foundation for others to use it. In one of his articles, he describes modeling as “the name of game” in science and technology and explains that it should be the central theme of science education (Hestenes, 1993). He describes modeling as a powerful way of thinking used to understand the structure of things, natural processes, and creating conceptual models. This is particularly important because conceptual models are different from concrete models in that conceptual models are based on ideas and concrete models are based on physical materials. Modeling is exceptionally important in science and math curriculum because studies have shown statistically significant results in the natural sciences and engineering areas of higher education. In order to appreciate modeling, one should understand its role and how it applies scientific knowledge in general. The article “Modeling is the Name of the Game” by Hestenes describes several areas that target the fundamentals based on modeling instruction. Hestenes discusses conceptual models, objects and models with structure, structure of the natural world, modeling in math and science curriculum, and answers the question about what makes knowledge scientific (Hestenes, 1993).

Scientific knowledge is different from ordinary knowledge due to objectivity, precision, and structure. Hestenes explains that these aspects are sometimes missing in introductory science textbooks and that in order to develop those types of thinking patterns, we must have a clear idea of how this is achieved in science. Science is concerned with natural things and processes and therefore needs to be compared to other processes in order to be better understood. Comparisons are made in order to become objective and procedures need to be followed to compare objects with respect to their properties. If these habits are developed early, and students learn to think objectively, this will reduce their own subjective perceptions for scientific knowledge (Hestenes, 1993).

Models in the conceptual world are typically validated conceptual models of natural matter and represent matter or their properties in the concrete world. Modeling begins with descriptors that represent a property of the object in question. There should be a distinction between concrete properties and conceptual descriptions, but this is often lacking. Thus, the standards of objectivity and precision are not met. It is not until theses standards are met that a conceptual model is to be validated. Descriptors of nature fall into three broad categories of physical, chemical, and biological natural laws. Properties fall into intrinsic and interactive categories. Intrinsic properties are individual, while interactive properties are shared with other things. Some properties stay the same, while others change. All of these should be considered when trying to determine a model. A conceptual model should be defined by specifying constituents (name of thing of interest and environment), descriptors (variables and interactions), laws (laws of change and interaction laws), and interpretation (relating descriptors and properties) (Hestenes, 1993).

There are two types of concrete systems, natural and artificial. “Scientists aim to discover the structures of natural systems and represent them accurately with models. They have a huge body of evidence for a general theory of nature: 1) Any concrete system can be separated into systemic and spatial parts that are connected by natural laws. 2) The natural world is composed of semi-permanent systems (i.e. atoms, molecules, etc.). 3) Natural systems are organized into different levels of structural complexity. 4) Every property of a concrete system as a whole is either resultant or emergent (inherited or not possessed by its constituents). 5) Structural explanation” (Hestenes, 1993). This theory of nature allows scientists to break things down and form models of these ideas or processes. If any system can be separated into parts or systems and different levels of structural complexity, models can be formed. The properties of these systems exist or emerge, but when broken down can be explained using a model and this then allows for an explanation of that structure (Hestenes, 1993).

Modeling helps identify important factors and eliminate irrelevant information while organizing complex information systematically. It facilitates planning and allows access to scientific knowledge to those who understand its origin through modeling. Modeling also offers protection from misconceptions with an ability to recognize scientific claims. Lastly, it offers a certain appreciation of the wonders of the world by creating models understood by science. “Modeling is a means to discover and create order in the fabulous world of everyone’s experience” (Hestenes, 1993).

Malcolm Wells, David Hestenes, and Gregg Swackhamer wrote a journal article titled “A Modeling Method: for high school physics instruction.” The abstract states, “Objective evidence shows that the modeling method can produce much larger gains in student understanding than alternative methods of instruction” (Wells et al., 1995). Tests were conducted on three different high school physics classes that were each instructed by very different approaches. One class learned by cooperative inquiry, one by modeling method, and one by traditional method. The cooperative inquiry was student centered, activity oriented, and laboratory based. In this type of instructional method, students are actively engaged in investigating and collaborating with their peers under instructor guidance. Most of this particular class was laboratory based and the class and homework problems were designed by the teacher or pulled from textbooks to expand on concepts from the lab work. The modeling method used is described in this article as “cooperative inquiry with modeling structure and emphasis.” All the ideas remained the same as the regular cooperative inquiry, but the difference was the emphasis on using models and modeling instruction. The instructor guidance was focused on a modeling agenda, which meant that student investigations and presentations became coherently structured. This setup meant that the entire course and subject had a net result of increased coherence of the subject matter. Lastly, the traditional method used a standard textbook, lectures, demonstrations, and homework problems to reinforce concepts. Lab activities were not used as much as in the cooperative inquiry or in the modeling method and were designed to reinforce concepts from class and to develop lab skills (Wells et al., 1995).

All three of these high school courses (inquiry, modeling, and traditional) had the same number of students and all covered the same topics as agreed by the teachers. In the diagnostic posttest scores, the modeling class increased 19% more than the inquiry-based class and 15% more than the traditional class. These results are substantial because the standard deviation of scores did not exceed 16% for any of the three classes. The pretest scores of the inquiry and traditional classes did not show much difference between the two methods because the pretests scores were both low. However, the inquiry had a 9% greater gain than the traditional method. These results show that cooperative learning is not likely to improve student learning alone. Careful instructional design in addition to cooperative learning can improve student achievement results (Wells et al., 1995).

In another study, Modeling was used to teach problem solving in introductory mechanics and was evaluated by a pedagogical experiment in a study by Hestenes and Halloun. Modeling methods have shown to be academically successful according to the article titled “Modeling Instruction in Mechanics” (Hestenes and Halloun, 1987). Poor performance on physics examinations is typical in introductory mechanics and suggests that conventional teaching methods are not ideal for student success. This study used the conventional lecture method for exposing modeling techniques and principles to solve problems in mechanics. Although this style was not expected to be effective alone, the authors developed another approach to make greater use of instructional theory. The study decided that because of defective procedural knowledge in the “formula-centered” approach, an instructional method that promoted a model-centered approach should be used to solve problems. The researchers used a method with three major features: 1) a systematic design and selection of problems for intensive study, 2) a dialectical teaching strategy, and 3) a gradual introduction of modeling theory and techniques (Hestenes et al., 1987). The problems were chosen to challenge typical misconceptions in physics.

Another set of problems then required complete modeling techniques for their solutions. There were very specific ways the instructor used the information given and modeled the solution. Lastly, the instructor was guided by the principles and techniques of modeling theory, which were introduced as needed. The experiment was designed to test whether or not student achievement in physics could be improved by incorporating a systematic discussion of modeling techniques into class lectures, and to test whether or not student achievement could be further improved by employing the method of paradigm problems in recitation classes (Hestenes et al., 1987).

In this study, the student population, course content, and textbook were the same for all courses, and each was taught by conventional lecture-recitation methods. They were divided into four groups; three treatment groups and one control group. For baseline data, these groups were also divided into competence classes of high, average, and low based on physics-math pretest scores. An analysis of variance (ANOVA) test was used to measure their competency levels as measured by the diagnostic tests. This study concluded that all treatment groups achieved higher gains than the control groups on their regular class examinations and on the mechanics diagnostic test. Other ANOVA tests were used to measure physics pretest-posttest gains and various sub-group's overall achievement in the course. The standard deviations for pretest scores were not significantly different. However, on regular class examinations, the difference between control groups and treatment groups rose from 6.45% on the first exam to 12.66% on the second. One exam consisted of problems where a diagram was almost required to solve the problem. About 85% of the treatment groups drew diagrams, compared to 40% of the control groups. 50% of the trained group and 20% of the control group were able to correctly draw these diagrams. Extra hours of recitation using conventional problem solving also had little effect on student achievement (Hestenes et al., 1987).

The modeling method is designed to correct several weaknesses of traditional lecture-demonstration teaching as stated in the "Modeling Methodology for Physics Teachers" journal article (Hestenes, 1997). This includes knowledge, student passiveness, and common misconceptions. The instructional objectives of modeling are designed to engage students in understanding the physical world by using models to explain, predict, design, and control physical phenomena. These objectives also aim to provide students with basic conceptual tools for modeling objects and processes. Another purpose of modeling is to provide a small set of basic models for core knowledge and eventually expand on those. Modeling is designed to develop insight into the structure of scientific knowledge and show how evaluating those scientific models validate knowledge (Hestenes, 1997).

Teaching by modeling should be done from the very beginning of the school year to allow students to become accustomed to this style. The instruction should be organized into cycles that engage students in all phases of modeling. The teacher should set the stage for this structure by performing a demonstration and discussion to establish common understanding (Hestenes, 1997). Usually, there is a question to be answered or problem to be solved. Students then collaborate and conduct experiments to answer or clarify the question or problem. The students are required to present and justify their conclusions in oral and/or written form and evaluate other models by comparison. The teacher becomes more of a facilitator who monitors student progress and guides student inquiry. The instructor also addresses misconceptions as needed (Hestenes, 1997).

Hestenes writes about a survey administered that included over 12,000 students in 100 physics courses at various high schools, colleges, and universities across the country in his “Modeling Methodology for Physics Teachers” journal article. This vast amount of data presented a consistent picture showing that the Force Concept Inventory provides statistically reliable measures of minimal performance in mechanics (Hestenes, 1997). The results concluded that before students are exposed to physics, their original thoughts and beliefs about mechanics are incompatible with Newtonian concepts; those beliefs also determine performance in introductory physics. This study also concluded that traditional lecture-demonstration physics only changed those beliefs a small amount. The greater changes in student belief came from non-traditional instructional methods. The scores from fourteen pre and posttests scores found a mean normalized gain of 22%, with the largest gain of 32%. Using 41 courses from non-traditional teaching methods, there was a mean gain of 52%, with the largest gain of 69%: Those two means differ from several standard deviations, meaning that the end result is highly significant. Overall, the traditional structure fails in meeting the minimal standards (Hestenes, 1997).

After researching the positive effects of Modeling instruction, the idea of this study came about. Knowing that it had positive effects on college and high school physics classes raised the idea of performing modeling instruction in a different high school setting.

MATERIALS AND METHODS

The purpose of this experiment was to determine the effects of a first attempt at modeling instruction on student achievement compared to traditional instruction. The groups used for this study consisted of sophomores and juniors in high school Chemistry courses. One group was taught by traditional instruction, the control group and the second group by modeling instruction, the experimental group.

The entire sample was made up of one hundred twenty-nine students and is broken down in Table 1:

Table 1: Entire sample broken down into gender and grade level

Group:	Total	Males	Females	Sophomores	Juniors
Modeling	55	17	38	19	36
Traditional	74	25	49	39	35

The sophomores and juniors were mixed in together in all of these classes although there was not an even balance between the two groups. This mixture is notable because the juniors were exposed to Physical Science before taking the Chemistry class, while the sophomores went straight to Chemistry from Biology without first being exposed to Physical Science. These students ranged in age from fifteen to eighteen and were of different socioeconomic backgrounds broken down in Table 2:

Table 2: Demographic breakdown of entire sample

Demographics	N=129		
Race:	49% Caucasian	49% African-American	2% other
Lunch:	43% free lunch	10% reduced lunch	47% full price

The school used a block schedule, where students had seven different classes over two days, A-day and B-day. A-day kids were taught by traditional instruction and consisted of four blocks per day. B-day kids were taught Chemistry using modeling instruction and consisted of three blocks per day. Over a two-week time period, A-day and B-day were alternated every other day, giving each sample the same amount of instructional time and hours.

The control group was taught traditionally using lectures and regular note taking and the experimental group was taught using modeling instruction based on what day that group went to class. The traditional sample used a textbook and took notes each day from the lecture. This group was required to take tests based on the textbook chapter and have regular quizzes. The instructional order of the textbook was followed. Students completed section reviews and chapter reviews for each chapter.

The experimental group was taught using the Modeling Curriculum provided by Arizona State University. The students worked together daily in groups to solve problems and used white boards to present information and problems to the class. The experimental group was more hands-on than the control group and self-discovery methods were encouraged. The teacher would demonstrate an experiment or problem and lead into a whole group discussion to introduce a new idea or concept. The students then broke off into groups to work through the problem to determine an answer. After all groups were done white-boarding their answers, they would present them to the class. It was at this point that the rest of the class compared their answers to other groups in order to reach a conclusion. If someone made a mistake, or each group didn't agree on what the answer should be, it was easily determined based on what the other groups concluded. It was this whole-group comparison that clarified some common misconceptions. Groups were required to explain how they determined their answers, and when all didn't agree, it was more likely explained by a group of students rather than the teacher.

The experimental group was taught by modeling and the control group was taught by traditional methods throughout the school year. The purpose of this study was to determine whether or not there was a difference in these two teaching styles by evaluating students' performance utilizing several tests at the beginning of the year and again at the end of the year. The students' knowledge of specific chemistry concepts, their ability to reason scientifically, and their attitudes about chemistry were evaluated based on the type of instruction they received.

Each sample was held equally accountable by having the same number of total possible points for each semester. They had the same number of tests, grades, and homework assignments, although they may differ from experimental group to control group.

Concept inventories are created and designed to evaluate the knowledge of a specific set of concepts and are based on extensive research. They are evaluated and studied to determine their validity. Questions include a correct response with other distractors based on commonly held misconceptions and are used to determine whether the student mastered knowledge on the content. The Chemistry Concept Inventory (CCI) (Robinson, 1996) is an instrument designed to show the level of misconceptions in introductory chemistry. It is composed of conceptual chemistry questions and is designed for a first year general chemistry course. It has twenty-two questions that are designed to test mastery of the content. It was originally administered to 1400 students who had all taken a high school Chemistry course and the results showed that many of those general Chemistry students were not proficient with significant parts of general Chemistry concepts (Robinson, 1996). It was developed by Doug Mulford in 1996 as part of his graduate study to determine whether or not students mastered chemistry concepts and disregarded typical misconceptions. The Chemistry Concept Inventory is generally given to first year college students as a method of evaluation. It was used to determine whether or not students gained knowledge of chemistry from the beginning of the year to the end of the year.

The Classroom Test of Scientific Reasoning (CTSR) (Lawson, 1987) was used to test students' ability to apply aspects of scientific and mathematical reasoning. The Classroom Test of Scientific Reasoning incorporates questions where students' analyze situations and make predictions or solve problems. It incorporates questions that require application responses, in addition to the questions, to justify those answers. The test is made up of twenty-four multiple-choice questions that measure higher-level cognitive skills. A situation is described in a few short sentences and a problem is presented, requiring students to use judgment and critical thinking in order to correctly answer them (Lawson, 1987). This test, like the Concept Inventory, was given at the beginning of the year and again at the end of the year to determine whether modeling or traditional instruction had an affect on students' abilities to reason.

The Colorado Learning Attitudes about Science Survey-Chemistry test is a test that describes a student's beliefs about learning chemistry. This test will show if there were any differences in attitudes about Chemistry from traditional learning methods as compared to modeling instruction. The main goal of the Colorado Learning Attitudes about Science Survey (C-LASS) is to compare student to expert perceptions about the content of specific disciplines to real world approaches. In this case, Chemistry is the specific subject, although there are other attitude tests regarding other content areas. "Preheld beliefs about a discipline can strongly impact conceptual learning by affecting how a student approaches learning and makes sense of a particular area of study." (House et al. 1994, Perkins et al. 2005) The instruments designed to compare these tests have an ability to detect student to expert differences by comparing their responses. "Work indicated students can directly identify expert responses to C-LASS instrument statements, but will still answer honestly about their own perceptions regardless of whether or not they agree or disagree with expert response." (Adams et al. 2006) (Gray et al, 2008). This idea reasonably shows that the instruments reflect student thoughts accurately and not what student's think their instructors want them to think. "An individual student's overall % favorable score is comparable to the student's agreement with the expert response and the overall % unfavorable is comparable to the student's disagreement with the expert response (Barbera, et al., 2008). This C-LASS test is composed of fifty questions that allow for responses of strongly disagree, disagree, neutral, agree, or strongly agree. Neutral responses are not grouped as favorable or unfavorable. These statements are designed to describe one's belief about learning chemistry. If no strong opinion or feeling about a statement is obvious, neutral should be selected. The C-LASS Chemistry survey has been administered in over 30 courses at a variety of universities (Barbera, et al., 2008). This test was based off of the VASS – Views about Science Survey and the MPEX – Maryland Physics Expectations Survey (Perkins, et al., 2005). This C-LASS was strictly about Chemistry although there are other subject specific tests using the same concept.

Two regular classroom examinations were administered as traditional measures of student achievement. These included a test on nomenclature (the naming of compounds) and the Final Exam. The Nomenclature Test was a fifty question test with twenty-five questions requiring the students to name the correct compound when given the formula and twenty-five questions requiring the student to write the proper formula when given the name of the compound (Appendix). These formulas and names were of all different types of compounds and all possessed different rules for naming. The Final Exam was also a teacher-made test and was composed of questions based on general Chemistry knowledge that a typical high school student should learn in a high school Chemistry class. Although the material was presented differently throughout the year for the two groups, the requirements for what they should have learned were all the same based on the grade level expectations for Chemistry.

DATA ANALYSIS/RESULTS

Statistical analysis of the pretests and posttests of this study employed ANOVA and t-tests for group comparisons. The purpose of these two tests is to determine whether or not there is a difference between different samples in the study (t-test for two groups and ANOVA for multiple groups). All of the tests were done at a 95% confidence level (alpha = 0.05). If between the two groups the p-value is less than 0.05, it can be reasonably assumed that there is a difference. If the p-value is greater than 0.05, we can assume that the populations are identical so there is no difference between the samples.

Both raw and normalized gains were evaluated. Raw gains show the difference in raw scores from the pretests to the posttests. The normalized gain accounts for a wide range of students' pretest scores by looking at student's achievement for potential gain. The posttest score minus the pretest score divided by total possible points minus the pretest is used to calculate the normalized gain. The following is the equation for normalized gain, g (Hake, 2002).

$$g = \frac{(posttest\_scores) - (pretest\_scores)}{(total\_possible) - (pretest\_scores)}$$

Equation 1 Normalized Gains

The pretest scores for the CCI and the CTSR were analyzed to compare the knowledge level of students at the beginning of the school year. The Chemistry Concept Inventory was administered to students at the beginning of the year as well as at the end of the year in an attempt to determine whether or not there were any learning gains from the pretest to the posttest. Before the normalized gains were calculated for the two samples, a one-way ANOVA showed no difference between any of the seven classes in the sample from the pretest as indicated by a p-value of 0.57. For the Classroom Test on

Scientific Reasoning comparing modeling to traditional students using a t-test gave a p-value of 0.19. From this number, we can assume that both groups started out at about the same level as far as their scientific reasoning skills are concerned. The average pretest score for the CCI was a 23% for Modeling and a 24% for Traditional. The average pretest score for the CTSR was a 41% for both the Modeling and Traditional samples. From these test results, it can be determined that differences in gender and the fact that some students had a Physical Science background show no difference between the groups at the beginning of the school year's pretest data. Table 3 shows the average pretest and posttest scores for the CCI and the CTSR.

Table 3: Average pre and posttest scores for the CCI and CTSR for Modeling and Traditional Samples

	CCI		CTSR	
	Pretest	Posttest	Pretest	Posttest
Modeling	23% ± 1%	36% ± 2%	41% ± 2%	49% ± 2%
Traditional	24% ± 1%	27% ± 2%	41% ± 2%	44% ± 2%

After the posttest was administered comparing the two samples, a p-value of 6.5×10^{-5} showed that there was a statistical difference between the modeling sample and the traditional sample for the CCI. The average posttest score for Modeling was a 36% compared to the posttest score for the traditional group of a 27%. The p-value indicates that there is a difference in retention of Chemistry concepts between the experimental group and the control group based on the Chemistry Concept Inventory.

After determining that both samples started out at about the same level, normalized gains for both samples on the CCI and the CTSR were analyzed. Table 4 indicates the normalized gains for the Modeling and traditional sample groups for the Chemistry Concept Inventory. The Modeling experimental group showed statistically significant differences in their normalized gains for the posttest as well as their actual average gains from Table 3. Table 4 breaks down each class by teaching style to show the normalized gain, and includes the standard error of the mean. Figure 1 shows the normalized gains of the Chemistry Concept Inventory from pretest to posttest as shown in Table 4. These normalized gains are broken down into individual classes where the 1^{st} through 4^{th} blocks were the traditional control group and 6^{th} through 8^{th} blocks were the Modeling experimental group.

Table 4: Normalized Gains for the Chemistry Concept Inventory for Modeling and Traditional sample groups. (1^{st}-4^{th} Traditional and 6^{th}-8^{th} Modeling).

CLASS:	NORMALIZED GAINS
1^{st} Traditional	3% ± 4%
2^{nd} Traditional	7% ± 3%
3^{rd} Traditional	8% ± 5%
4^{th} Traditional	1% ± 3%
6^{th} Modeling	15% ± 3%
7^{th} Modeling	21% ± 4%
8^{th} Modeling	12% ± 4%

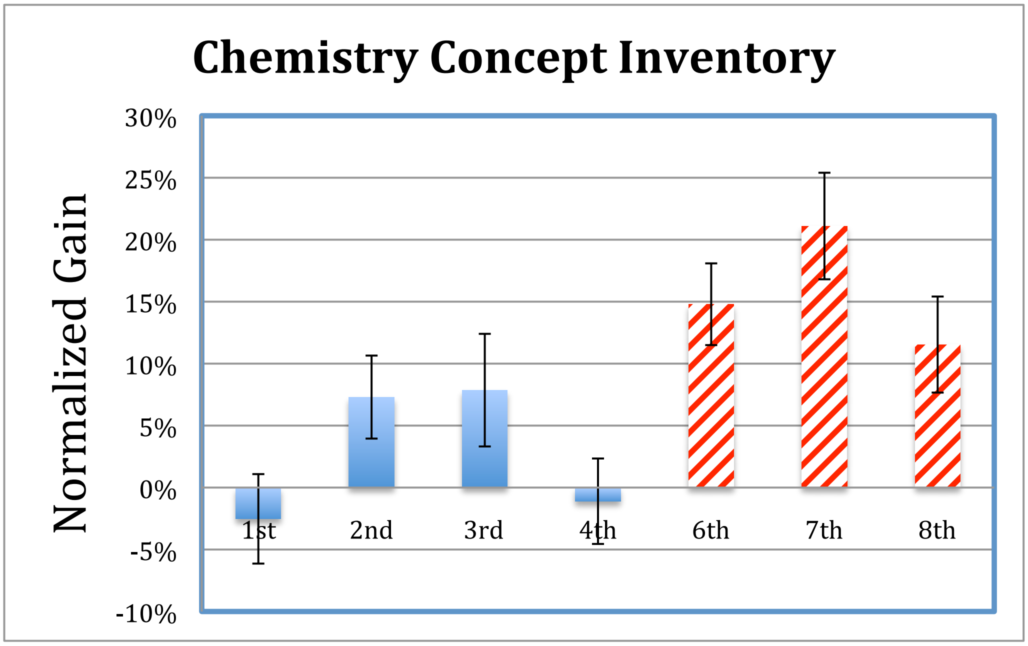

Figure 1: Normalized Gains for the Chemistry Concept Inventory for Modeling and Traditional sample groups (Traditional 1^{st}-4^{th}) (Modeling 6^{th}-8^{th})

Another t-test was conducted to determine whether or not there was any difference between genders. Table 5 breaks down the gender performance between the Modeling and traditional samples. A t-test was performed to compare the males from the Modeling sample to the males from the Traditional sample and the females from the Modeling sample to the females from the Traditional sample for the Chemistry Concept Inventory. According to the data analysis, there is a statistically significant difference between the methods. The Modeling seemed to benefit both genders equally.

Table 5: Normalized Gains for Males and Females in the Modeling and Traditional Samples for the Chemistry Concept Inventory

STYLE - GENDER	NORMALIZED GAINS
Modeling - Males	17% ± 4%
Traditional - Males	1% ± 4%
Modeling - Females	16% ± 3%
Traditional - Females	4% ± 2%

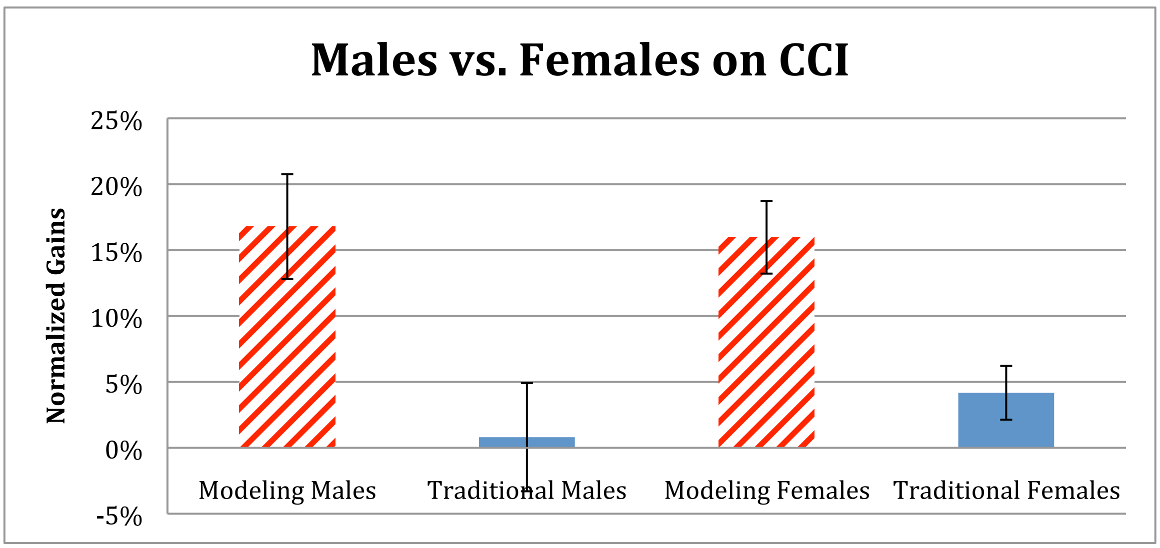

Figure 2: Normalized Gains for Males and Females in the Modeling and Traditional Samples for the Chemistry Concept Inventory

Figure 2 shows the normalized gains for the CCI broken down by gender for each instructional method. A t-test shows that there is no significant difference ($p > 0.05$) between gender in Modeling and traditional instruction for the CCI test. When Modeling males were compared to traditional males, a statistically significant difference was shown by a p-value of less than 0.05 indicating modeling instruction was more effective. The same was true for the modeling females compared to traditional females ($p < 0.05$) where modeling was a more effective method. Modeling appears to be more effective as a style, but whether you are male or female does not appear to matter. Males and females were affected the same way in both the traditional style and in the Modeling style.

Another interesting comparison was to test the effect of instructional methods by comparing sophomores to juniors. The purpose of this comparison was to determine if prior exposure to Physical Science had any effect on learning Chemistry. In all of the classes, juniors and sophomores were mixed together. All of the juniors had Physical Science prior to Chemistry, but the sophomores had never been exposed to that class. A p-value of 0.475 as indicated by a t-test for the Modeling sample on the CCI pretest (average 23% ± 1%), indicated there was no significant statistical difference from the sophomore to junior sample ($p > 0.05$). A p-value of 0.819 for the traditional sample for the CCI pretest (average 24% ± 1%) also showed no statistically significant difference in prior exposure for the different grade levels (Table 6, Figure 3).

Table 6: Normalized Gains comparing prior exposure to Physical Science (sophomore vs. junior) and standard error of the means for CCI

STYLE - PRIOR EXPOSURE	NORMALIZED GAINS
Modeling – Sophomores	14% ± 4%
Traditional - Sophomores	3% ± 4%
Modeling - Juniors	17% ± 4%
Traditional - Juniors	3% ± 4%

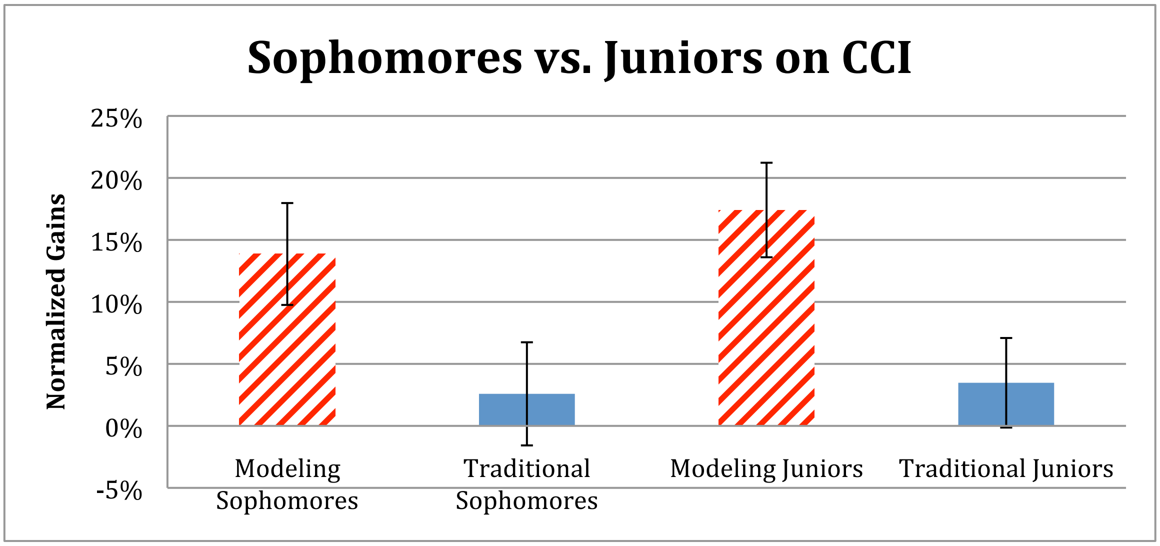

Figure 3: Normalized Gains comparing prior exposure to Physical Science (sophomore vs. junior) and standard error of the means for CCI

Figure 3 shows the normalized gains comparing prior exposure to Physical Science for the Modeling and traditional samples. The Modeling method produced higher normalized gains, independent of students' prior exposure to Physical Science. This similarity indicates that Modeling instruction is appropriate for both grade levels.

Normalized gains, gender differences, and background in Physical Science were also calculated for the Classroom Test on Scientific Reasoning. Table 7 shows the normalized gain for the CTSR scores for both the group taught by Modeling and the group taught traditionally. A t-test determined a p-value of 0.28 for the normalized gains from pretest to posttest indicating that there was no statistically significant difference in the Modeling group and traditional group for the CTSR test. One could infer from these results that Modeling instruction for only one year in high school, when compared to traditional instruction, does not have a significant effect on students' abilities to reason scientifically. Figure 4 shows the normalized gains for both samples, Modeling and traditional for the CTSR. There is no statistically significant difference in normalized gains between the two samples for the Classroom Test on Scientific Reasoning as indicated by a p-value of greater than 0.05 based on a t-test.

Table 7: Normalized Gains for the CTSR for Modeling and Traditional sample groups. (1^{st}-4^{th} Traditional and 6^{th}-8^{th} Modeling).

CLASS	NORMALIZED GAINS
1^{st} Traditional	10% ± 4%
2^{nd} Traditional	1% ± 7%
3^{rd} Traditional	1% ± 11%
4^{th} Traditional	-1% ± 4%
6^{th} Modeling	4% ± 5%
7^{th} Modeling	17% ± 8%
8^{th} Modeling	16% ± 5%

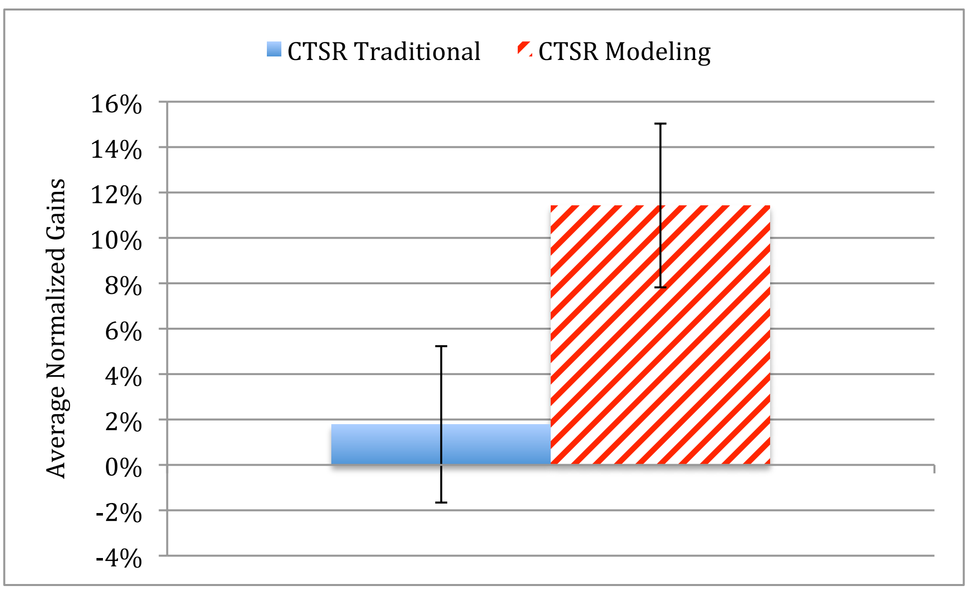

Figure 4: Normalized Gains for the CTSR for Modeling and Traditional sample groups

Gender differences were also compared between the two teaching styles for the Classroom Test of Scientific Reasoning. The p-value calculated by the t-test for the normalized gains for males was 0.07 and the p-value calculated by the t-test for the normalized gain for females was 0.21, indicating no statistically significant difference from the pretest to the posttest for differences in gender. Table 8 shows the normalized gains for the CTSR separated by gender and teaching style. Figure 5 shows the normalized gains for males and females in the Modeling and traditional sample for the CTSR. There is no statistically significant difference between males and females normalized gains for the CTSR based on the p-value given by a t-test of $p > 0.05$ for either sample.

Table 8: Normalized Gains for Males and Females in the Modeling and Traditional Samples for CTSR

STYLE - GENDER	NORMALIZED GAINS
Modeling – Males	23% ± 7%
Traditional - Males	8% ± 5%
Modeling - Females	6% ± 4%
Traditional - Females	-2% ± 4%

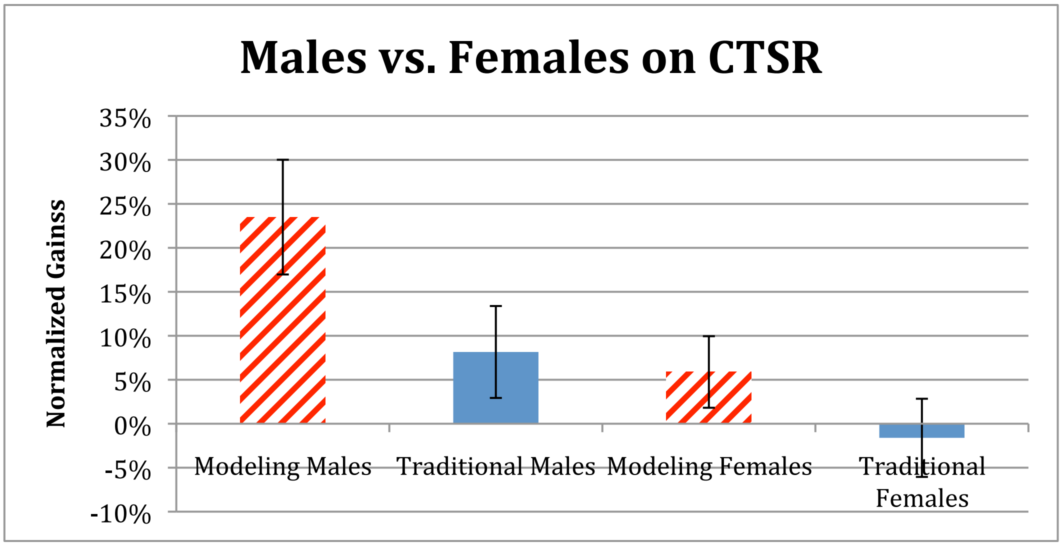

Figure 5: Normalized Gains for Males and Females in the Modeling and Traditional Samples for CTSR

In both sample groups, students that had a background in Physical Science and students that did not were mixed together. Data analysis and the use of a t-test were utilized to determine whether or not background knowledge could account for differences in students' scientific reasoning abilities. The normalized gains were calculated comparing sophomores to juniors for the CTSR in order to determine whether or not exposure to Physical Science had an affect on a student's ability to reason scientifically. Sophomores were not exposed to Physical Science, but juniors were. A p-value of 0.067 determined by a t-test for the normalized gains for the CTSR showed no statistically significant difference between sophomores' and juniors' scientific reasoning abilities. For the junior class, a p-value of 0.23 determined by a t-test for the normalized gains, again showed no statistically significant difference for their reasoning abilities when exposed to Physical Science across the Modeling and traditional samples. Therefore, there was no difference in ability level between the sophomores and the juniors for the test on scientific reasoning. Table 9 shows the normalized gains for each sample. Figure 6 shows the normalized gain for prior exposure to Physical Science. A p-value greater than 0.05 determined by a t-test indicated there were no statistically significant differences in normalized gains for students' prior exposure to the material. When broken down by each grade, there is no statistically significant difference, indicating that the Modeling curriculum is equally appropriate for both grade levels, regardless of the fact that one group had been exposed to some of the basic material before taking a Chemistry class.

Table 9: Normalized Gains comparing prior exposure to Physical Science (sophomore vs. junior) for CTSR

STYLE - PRIOR EXPOSURE - CTSR	NORMALIZED GAINS
Modeling – Sophomores	16% ± 5%
Traditional - Sophomores	2% ± 5%
Modeling - Juniors	9% ± 5%
Traditional - Juniors	1% ± 4%

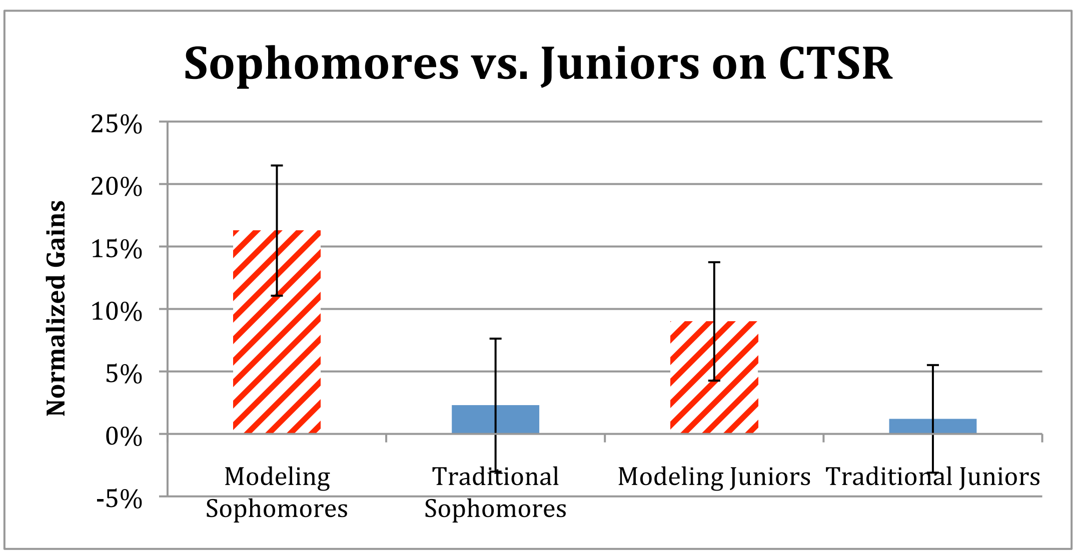

Figure 6: Normalized Gains comparing prior exposure to Physical Science (sophomore vs. junior) for CTSR

Another comparison to be made between the modeling sample and the traditional sample was to determine whether or not there were any changes in attitude about learning chemistry dependent on the way students were taught. This change in attitude could be measured by giving students the Colorado Learning Attitudes about Science Survey (C-LASS) for Chemistry as a pretest and posttest.

For the C-LASS survey, different questions were grouped into certain categories to determine if there were any similarities in attitudes regarding general problem solving, conceptual learning, and personal interest, among other things. From pretest to posttest, this test was used to determine whether or not student's attitudes about learning Chemistry shifted from favorable to unfavorable or vice-versa. The purpose of this test was to measure if traditional instruction had an effect on student attitudes as compared to Modeling instruction. Figures 7 and 8 show how attitudes shifted from the pretest to posttest in both sample groups. If from pretest to posttest, the color-coded symbol moved toward the top left of the graph, one can assume there was a loss of "bad" attitudes and a gain of "good" attitudes. If the symbol from pretest to posttest moved towards the bottom right, one can assume there was a gain of "bad" attitudes and a loss of "good" attitudes.

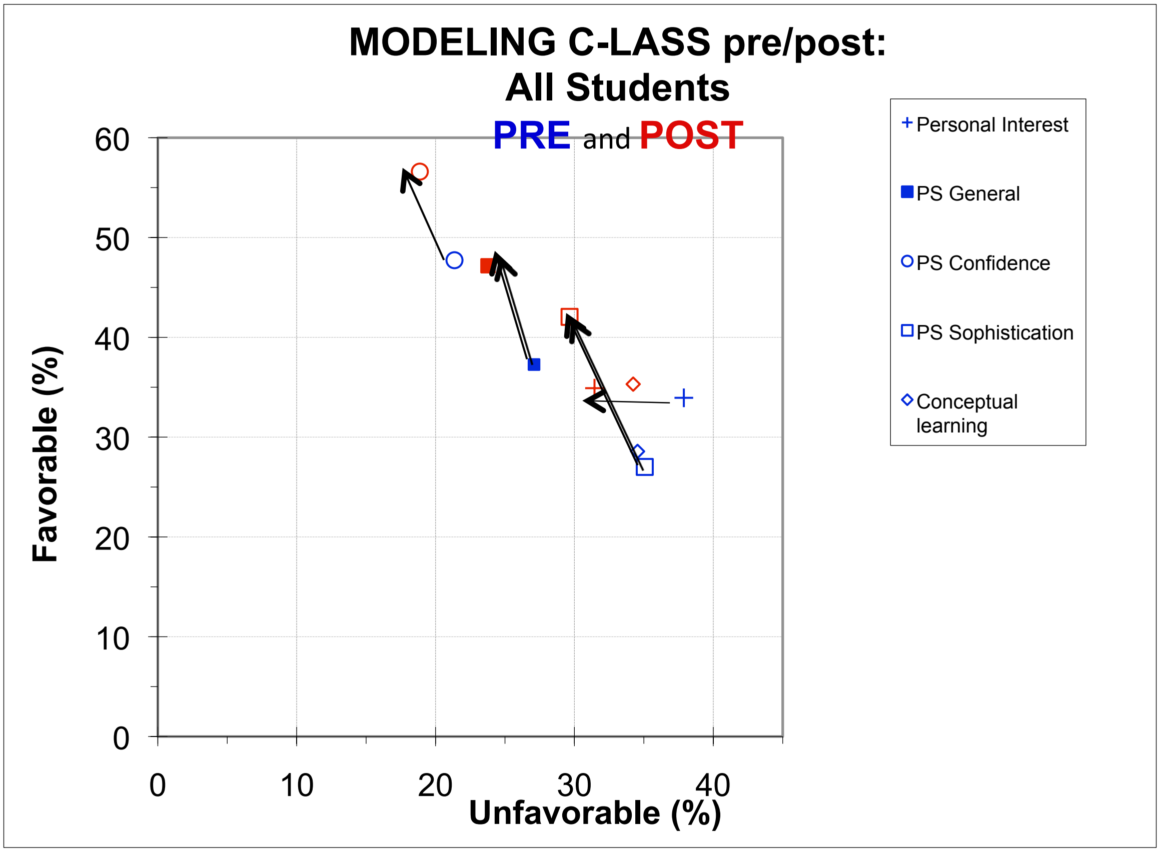

Figure 7: Favorable versus unfavorable attitudes on interest, confidence, sophistication, conceptual learning, and in general for the Modeling sample

Figure 7 shows that the Modeling sample had an overall shift towards the favorable percentage from pretest to posttest in each of the categories. This change means that for confidence, sophistication, conceptual learning, personal interest, and in general there were positive gains for the Modeling sample. Each category showed a favorable shift of attitude towards learning Chemistry because for each category, the pretest to posttest concept symbols moved toward the top left, indicating a gain of “good” attitudes. This data implies that students’ taught by Modeling instruction have positive attitudes about learning Chemistry.

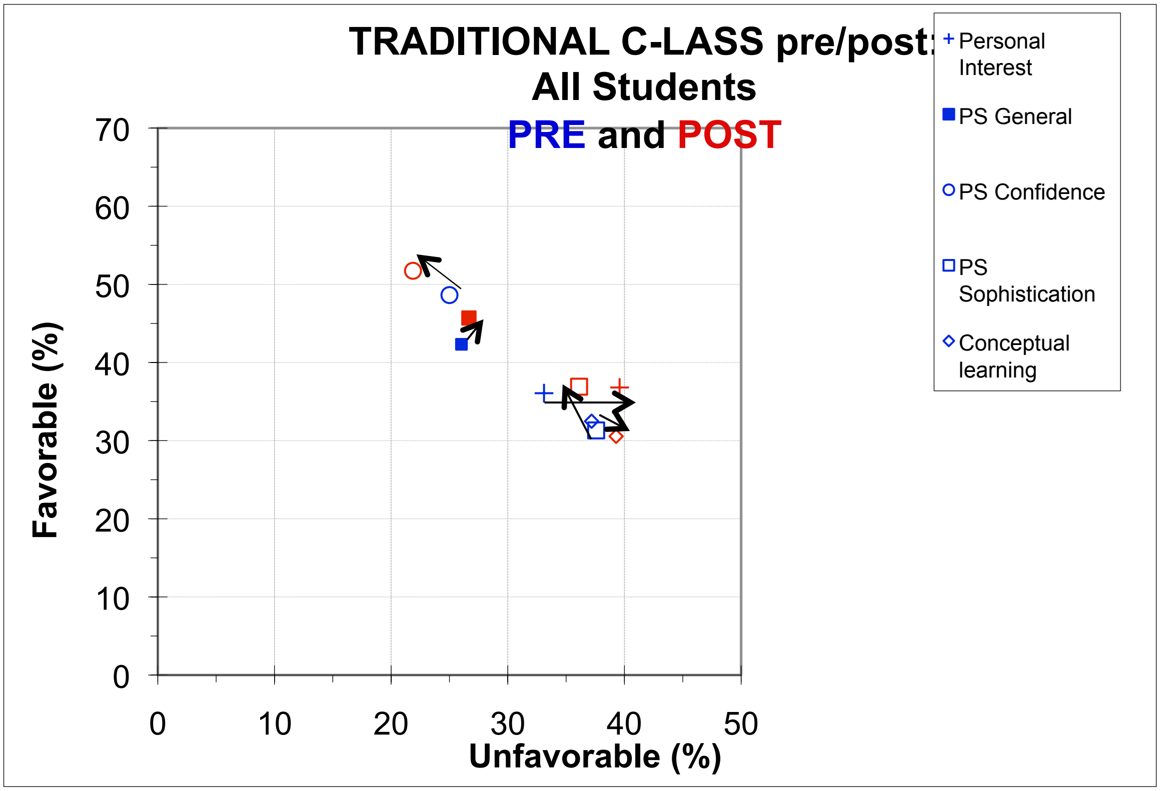

Figure 8: Favorable versus unfavorable attitudes on interest, confidence, sophistication, conceptual learning, and in general for the Modeling sample

Figure 8 shows that the Traditional sample, in more than one area, shifted towards the unfavorable percentage from pretest to posttest. There were positive gains in confidence and sophistication as indicated in Figure 8; however, there were negative gains in the general area, personal interest, and conceptual learning because each of these moved towards the bottom right from pretest to posttest, indicating a loss of "good" attitudes. This data reflects the idea that students that learned by Modeling had better attitudes towards Chemistry than students that learned by traditional instruction.

Taking a closer look at the data can provide a more detailed explanation of the attitudinal changes. The personal interest category is particularly interesting because of the significant opposite and large changes for both the Modeling and Traditional samples. Their horizontal slopes indicate that there is an absence of any change in favorable attitudes, indicating that all the change comes from their initially neutral or undecided opinions. For the Modeling sample, the pretest to the posttest sample shifts completely horizontal in the favorable direction. From this, it can be determined that students' went from a neutral opinion to a more favorable opinion. In contrast, for the traditional sample we see the exact opposite. From the pretest to the posttest, the sample shifts completely horizontally in the unfavorable direction. Because there was no favorable gain, it can be determined that opinions that were neutral or undecided shifted in the unfavorable direction. Modeling has a positive effect on personal interest, whereas traditional seemed to have a negative effect.

After a statistical analysis of all three tests used, one could argue that the goals of the tests in the Modeling instruction are aligned with the Modeling approach, so naturally there would be gains in this method. To account for this bias, two traditional summative tests were also compared for each sample instead of the CCI and CTSR pretests and posttests. These tests were the exact same tests given to both the experimental and control groups: a test on Nomenclature and the Final Exam. The Nomenclature test, required students to properly name compounds (Appendix A). The calculated p-value of 0.0042 given by a t-test for the raw scores shows that there is likely a statistically significant difference in the samples. The Modeling group performed statistically significantly better on this test than did the traditional sample.

Raw scores of the Final Exam which was a general chemistry concept test created by the teacher were also compared. When the p-value was calculated as 0.12 by a t-test for the final exam scores for each sample, one could reasonably conclude that there was no statistically significant difference between the two groups, although the Modeling sample did perform better as a whole. Reasons for no statistically significant difference could be because students were not as interested in the Final Exam and they were eager to be done for the year. Also, for several of the students, it was one of the few finals they had to take. However, the nomenclature test and the statistically significant difference in the two groups as calculated by a p-value of less than 0.05 given by a t-test shows that Modeling is effective for general chemistry concepts, even on a traditional test. The skills tested are still necessary for students to be responsible for in Chemistry no matter which way they are taught. Still, it can be reasonably concluded that teaching by Modeling instruction has a positive effect on student achievement. Table 10 shows the normalized gains for these two tests based on the sample groups. Figure 9 shows the normalized gains on the Nomenclature Test and the Final Exam for the Modeling and traditional samples. The Modeling sample had better raw scores on both tests. Although the Final Exam scores were not statistically significant, the nomenclature test scores were.

Table 10: Raw Scores for Nomenclature and Final Exam, for both Modeling and Traditional samples

STYLE	NOMENCLATURE TEST	FINAL EXAM
Modeling	88% ± 2%	77% ± 2%
Traditional	80% ± 2%	72% ± 2%

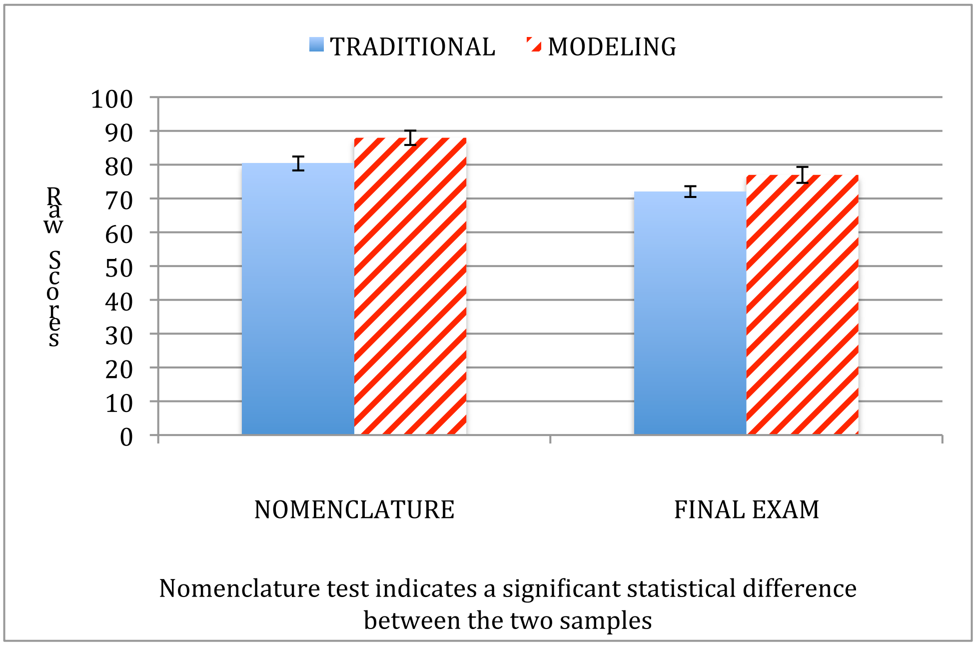

Figure 9: Raw Scores for Nomenclature and Final Exam, for both Modeling and Traditional samples

A difference was noticed in raw test scores and ability for the Nomenclature Test during the school year when it was given. It was at this point, that the question arose as to what could account for these differences in raw scores when the two groups were given the same test. This difference could have been because of how the material was presented in the traditional group as compared to the Modeling group. The traditional sample was given an example of an ionic bond and how they were named with several examples to follow. After that, they were given an example of how to name a covalent bond with several examples to follow. Next came polyatomic ions and transition metals in exactly the same format as portrayed by the textbook. Examples of each type were given separately, all of which follow different rules for naming. The Modeling sample, on the other hand, was exposed to each type all at once. Each type was explained and the practice was given with them all mixed up instead of separated like the textbook problems. Informal observations showed that it came much more easily and naturally when the Modeling sample was exposed in this manner. Both groups were required to learn how to name each type of compound, and because each type was mixed up on the test, in the end they were required to be able to do exactly the same thing. The traditional sample of students continued to get them confused, and it was difficult for them to differentiate between the types. The Modeling sample, on the other hand, was accustomed to having the different types of bonds already mixed up. Both groups were given the same exact test with problems that were mixed together and not separated by type of compound.

SUMMARY AND CONCLUSION

Different instructional methodologies can have an impact on student achievement when comparing the effects of Modeling methods and traditional methods. After analyzing the results in this study, there was in fact a significant gain of knowledge in chemistry concepts shown by the normalized gains for the Chemistry Concept Inventory for the Modeling group. The results also showed that there was a favorable shift in attitudes towards Chemistry for the Modeling sample when compared to the traditional sample. Other research has proven this Modeling to be an effective method, but this study shows that even for a first attempt at Modeling instruction, this effectiveness is still apparent. In the years before conducting this study, I taught my classes traditionally. After seeing how modeling can affect student learning, I plan to continue to use the modeling method. It is very engaging for the students and gives them the confidence and self-esteem they need to be successful in their high school Chemistry course. Modeling proved to have a positive gain in Chemistry concepts as well as improved students' attitudes about learning chemistry. If this method utilized in a high school can reduce the gap in common Chemistry misconceptions, I do not see why anyone would not use it for the betterment of education. This teaching style has also impacted me as a teacher in a positive way because students are learning, while staying involved and engaged in the subject matter. I feel like a better teacher because of how the students are learning and their continued interest in the subject. I enjoy my job even more teaching this way, because not only can lecturing be boring for the students, but for the teacher as well.

Modeling instruction is also a reasonable method economically for any teacher that wants to utilize it in their classrooms. It is not expensive like textbooks can be and only requires a two-week training course, the ASU Modeling curriculum, and a few inexpensive boards to use for white boarding exercises. It is outlined and easy to follow with guided teacher notes, power points, worksheets, activities, quizzes, and tests. Modeling is a technique that teachers can use if they are interested in working with something that is cheaper and easier than traditional teaching methods. Based on the results from my data, student investment in the method, and the ease in using the program, I would highly recommend Modeling to any Chemistry teacher who is looking to increase student achievement.

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APPENDIX A

Nomenclature Test

Name: ____ Date: _______Block: _____

Write formulas for the following compounds.

1. potassium chromate ____
2. copper (II) sulfide ____
3. magnesium nitrate ____
4. nickel(II) sulfate ____
5. lithium perchlorate ____
6. lead (IV) oxide ____
7. calcium iodide ____
8. barium nitride ____
9. cadmium bromide ____
10. aluminum acetate ____
11. diphosphorous trioxide____
12. sodium bromide ____
13. phosphorous pentachloride____________________________________
14. tetraphosphorous hexasulfide__________________________________
15. iron (III) carbonate ____
16. triphosphorous decasulfide____________________________________
17. aluminum oxide ____
18. potassium iodide ____
19. carbon tetrachloride ____
20. calcium sulfate ____
21. nitrogen monoxide ____
22. tin (IV) chloride ____
23. magnesium phosphate____
24. calcium oxide ____
25. dinitrogen tetroxide ____

Write the names of the following compounds.

26. KCN ______________________
27. SF_6 ______________________
28. $Al_2(C_2O_4)_3$ ______________________
29. $Cr(C_2H_3O_2)_3$ ______________________
30. CO_2 ______________________
31. $CuSO_3$ ______________________
32. $FeSO_4$ ______________________
33. NH_4OH ______________________
34. K_2O ______________________
35. $AsCl_5$ ______________________
36. N_2O_5 ______________________
37. $LiMnO_4$ ______________________
38. $(NH_4)_2C_2O_4$ ______________________
39. CsCl ______________________
40. Li_2S ______________________
41. CrO_3 ______________________
42. ClF_3 ______________________
43. MgO ______________________
44. $Fe_2(SO_4)_3$ ______________________
45. N_2O_4 ______________________
46. S_2Cl_2 ______________________
47. Cu_2O ______________________
48. CO ______________________
49. BBr_3 ______________________
50. LiF ______________________

APPENDIX B

Application for Exemption from Institutional Oversight

LSU

Institutional Review Board
Dr. Robert Mathews, Chair
131 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.6792
irb@lsu.edu
lsu.edu/irb

Unless qualified as meeting the specific criteria for exemption from Institutional Review Board (IRB) oversight, ALL LSU research/ projects using living humans as subjects, or samples, or data obtained from humans, directly or indirectly, with or without their consent, must be approved or exempted in advance by the LSU IRB. This Form helps the PI determine if a project may be exempted, and is used to request an exemption.

– Applicant,Please fill out the application in its entirety and include the completed application as well as parts A-E, listed below, when submitting to the IRB. Once the application is completed, please submit two copies of the completed application to the IRB Office or to a member of the Human Subjects Screening Committee. Members of this committee can be found at http://www.lsu.edu/screeningmembers.shtml

– A Complete Application Includes All of the Following:
(A) Two copies of this completed form and two copies of part B thru E.
(B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1&2)
(C) Copies of all instruments to be used.
*If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment material.
(D) The consent form that you will use in the study (see part 3 for more information.)
(E) Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB. Training link: (http://phrp.nihtaining.com/users/login.php.)
(F) IRB Security of Data Agreement: (http://www.lsu.edu/irb/IRB%20Security%20of%20Data.pdf)

1) Principal Investigator: Dana Browne **Rank:** Professor

Dept: Physics and Astronomy **Ph:** 578-6843 **E-mail:** browne@phys.lsu.edu

2) Co Investigator(s): please include department, rank, phone and e-mail for each

Jacqueline Barker
LaMSTI Program -Graduate Student
(225) 776-2403
jacquelinebarker@alumni.lsu.edu

IRB# E5610 LSU Proposal # ____

☒ Complete Application

☒ Human Subjects Training

3) Project Title: The Effects of Modeling Instruction vs Traditional Instruction

Study Exempted By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Exemption Expires: 8-17-2014

4) Proposal? (yes or no) NO **If Yes, LSU Proposal Number** ____

Also, if YES, either ○ **This application completely matches the scope of work in the grant**
OR ○ **More IRB Applications will be filed later**

5) Subject pool (e.g. Psychology students) Iberville Math, Science, and Art Academy 11th graders

*Circle any **"vulnerable populations" to be used:** (children <18; the mentally impaired, pregnant women, the ages, other). Projects with incarcerated persons cannot be exempted.

6) PI Signature [signature] **Date** 30-JUNE 2011 (no per signatures)

** **I certify my responses are accurate and complete.** If the project scope or design is later changes, I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at LSU for three years after completion of the study. If I leave LSU before that time the consent forms should be preserved in the Departmental Office.

Screening Committee Action: Exempted √ Not Exempted ____ Category/Paragraph 1

Reviewer Mathews **Signature** [signature] **Date** 8/18/11

VITA

Jacqueline G. Barker was born in Baton Rouge, Louisiana, in August 1984. She attended elementary, middle, and high school in Baton Rouge, Louisiana. She graduated from St. Joseph's Academy in May 2002. The following August she entered Louisiana State University Agricultural and Mechanical College and in December 2007 earned a Bachelor's Degree. She entered the Graduate School at Louisiana State University Agricultural and Mechanical College in June 2010 and is a candidate for a Master of Natural Sciences. She is a high school Chemistry teacher in Iberville Parish and is currently teaching at the Math, Science, and Arts Academy-West Campus.